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Title: COLLABORATIVE RESEARCH WITH URS & UC SANTA BARBARA: DEVELOPMENT AND IMPLEMENTATION OF A CONTINUOUS DETECTION, LOCATION AND ANALYSIS SYSTEM FOR GLOBAL EARTHQUAKES USING LONG PERIOD WAVES

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Abstract

We have further developed a simple, yet powerful, method to locate worldwide earthquakes and determine their size. This method continuously maps global surface waves at very long periods into to a three-dimensional space spanned by the geographic coordinates and origin time. Because our system uses very long period surface waves and operates continuously, it can determine reliable magnitudes and locations even for great or "slow" earthquakes and experiences few operational problems in real time due to its constant load approach. To be able to translate the stacked surface wave amplitude that is determined by our system into a moment magnitude equivalent value, we carried out a calibration study, based on the data from 100 events with a magnitude over 6.0. We found that after performing a simple straight line fit to our data, most of the translated magnitudes agree within 0.2 magnitude units with the NEIC catalog magnitude. Furthermore, the location of the maximum stacked amplitude also shows an excellent agreement with the catalog location. In collaboration with staff at the National Earthquake Information Center (NEIC), we have developed a proof of concept analyst tool version of our system. We have also started to explore the use of different frequency bands of seismic waveform data to enhance the sensitivity of the system to different earthquake magnitude ranges. A pilot system is currently running in automated mode at the NEIC.

Investigations Undertaken

We have developed a very simple but powerful method of locating earthquakes using surface waves. Our locator carries out a continuous mapping of the surface wave arrivals from different stations and different periods onto a (global) grid, using group velocity based travel time corrections. This method has several advantages over conventional short period locators:

1. it can determine a reliable moment magnitude even for great earthquakes
2. it provides a good first estimate of centroid location and time, which can give a quick indication of source finiteness and directivity
3. it will indicate the enhanced long period seismic energy of tsunami earthquakes, events for which moment (and thus tsunami generating potential) are underestimated using body wave techniques
4. it can act as independent back up of traditional near real-time location methods, which occasionally miss or underestimate earthquakes
5. it is potentially able to detect very long period events, bridging the gap between geodetic and high frequency seismic monitoring
6. due to continuous operation it is less susceptible to operational problems

Furthermore, this system has potential for further development, as indicated by similar methods used to determine regional moment tensors and rupture models.

The investigations performed for this award include the following: calibration of magnitude calculation using over a year of waveform data; comparison of determined location values with catalog locations for events greater than 6.0; development of a prototype tool for analysts at the National Earthquake Information Center and a preliminary exploration of the use of different frequency bands of seismic waveform data to increase the sensitivity of the system to smaller earthquakes.

Results

To translate the global maximum in the stacked amplitude into magnitude, we analyzed more than a year of seismic waveform data of 15 global stations. We investigated over 100 events with a magnitude greater than 6.0 and performed a simple least squares curve fitting to find an appropriate calibration equation (Figure 1).

Currently the locator code does not carry out any type of distance correction. We plan to incorporate such a correction in a future version of the software, at which point we will need to re-calibrate the stacked amplitude-magnitude relationship. Even without this correction however, our translated magnitudes usually agree within 0.2 units with the NEIC catalog magnitudes (Figure 2). We have also written a set of standardized scripts that will facilitate any future recalibration process.

The location of the maximum stacked amplitude also shows an excellent agreement when compared to the catalog locations, especially when taking into consideration that the grid spacing is about 1° and the larger events will show the effects of source finiteness (Figure 3).

We have developed a prototype tool for use by the National Earthquake Information Center analysts. The software can be called with a specific start time and duration, will run the locator system and create a movie showing the spatiotemporal development of the global stacked amplitude (Figure 4). The movie also shows a display of the current catalog information and thus any events that have been missed or underestimated by the existing USGS system will be obvious. Although the final plan is for the locator software to run near real-time, this tool will be useful until this goal can be accomplished.

We have started to explore the use of different frequency bands in the locator (Figure 5), to enhance the sensitivity of the system to earthquakes of different magnitudes. Using shorter periods will enable the detection of smaller events (a range of 30 to 100 sec will bring the global detection level to 4.8 or lower), but will complicate the reliable analysis of great earthquakes. Therefore we are interested in incorporating different frequency bands in a spectrogram-like manner, to enable an event analysis in frequency, as well as in time, domain. Introducing the use of several frequency bands may also facilitate the identification of specific signals as noise and thus increase the reliability of the system.

A pilot system, named SLAQR (Surface Wave Locator and Associator in Quasi Real-time), was installed at the NEIC in cooperation with Dr. Paul Earle and has been operating since October. Currently, daily stacks are computed, displayed and stored automatically at the NEIC. This system includes a simple web interface (Figure 6), which enables us to review the results and study trends and long term behavior of the system. Adjustments are made to this test-bed as needed. For instance, recently, we have changed the weighting scheme for the amplitude stacks to use median values rather than mean, as a way of reducing the effects of outliers, which are usually caused by station glitches. This modification has been very successful in reducing these artifacts.

Non-technical Summary

We have further developed a locator system for the National Earthquake Information Center that can quickly and reliably locate global earthquakes down to a magnitude 5.5 and determine their magnitude. The method employed continuously projects seismic energy back to the source region and thus represents a new way of using the wave field produced by earthquakes. We have calibrated this system and have shown that the determined values of earthquake magnitude and location agree well with the USGS catalog, using more than one year of seismic waveform data. We have developed a prototype tool that may be used by analysts at the National Earthquake Information Center to display the results of the system together with the existing earthquake catalog in order to indicate any missing or underestimated events. We have also started to investigate the use of different frequency bands of the seismic signal to enable us to increase the sensitivity of the system to a broader range of earthquake magnitudes and enhance its reliability.

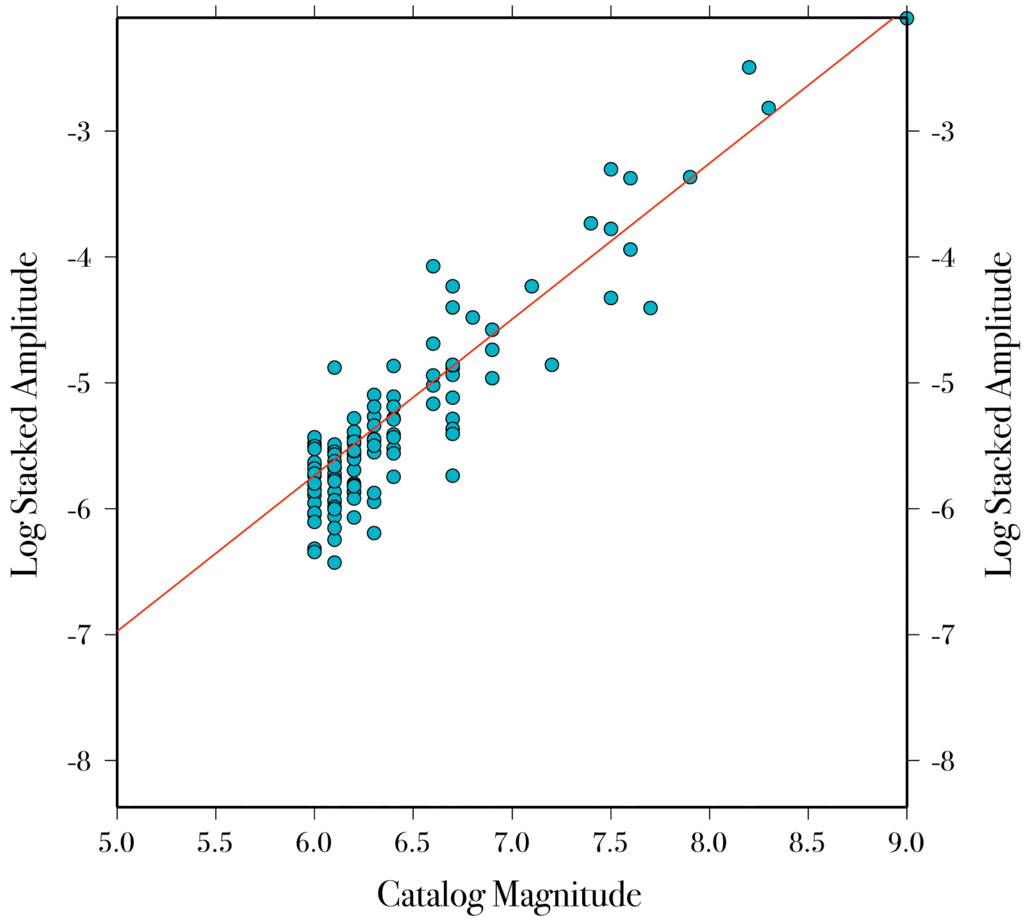

Figure 1: Calibration of stacked amplitudes in frequency band of [60,150] sec to magnitude.

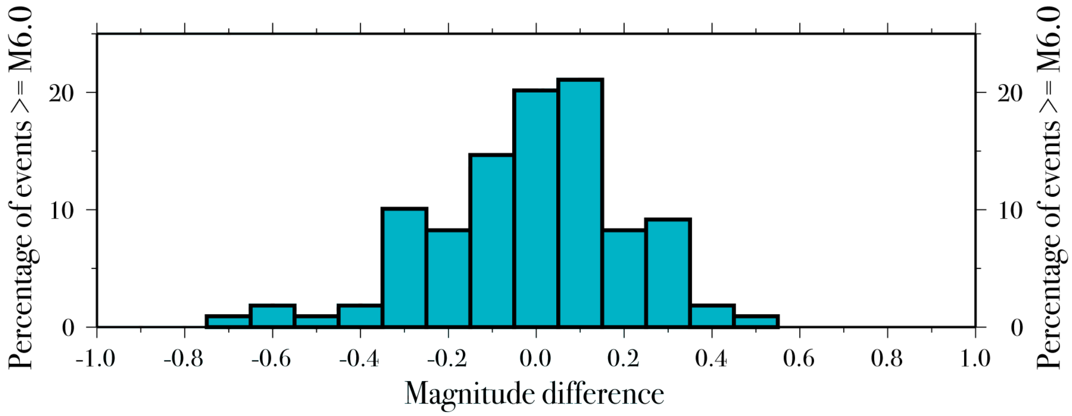

Figure 2: Magnitude difference between locator magnitude and catalog magnitude for all events greater than M6.0.

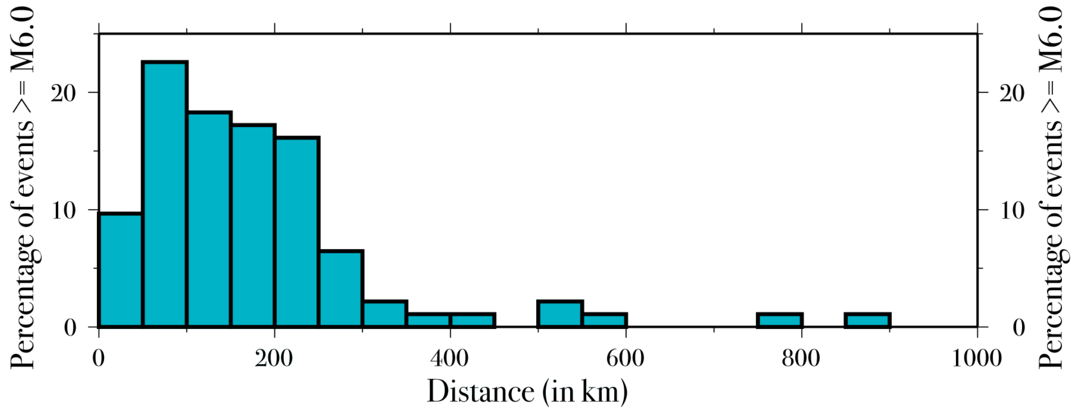

Figure 3: Distance between locator location and catalog location for all events greater than M6.0.

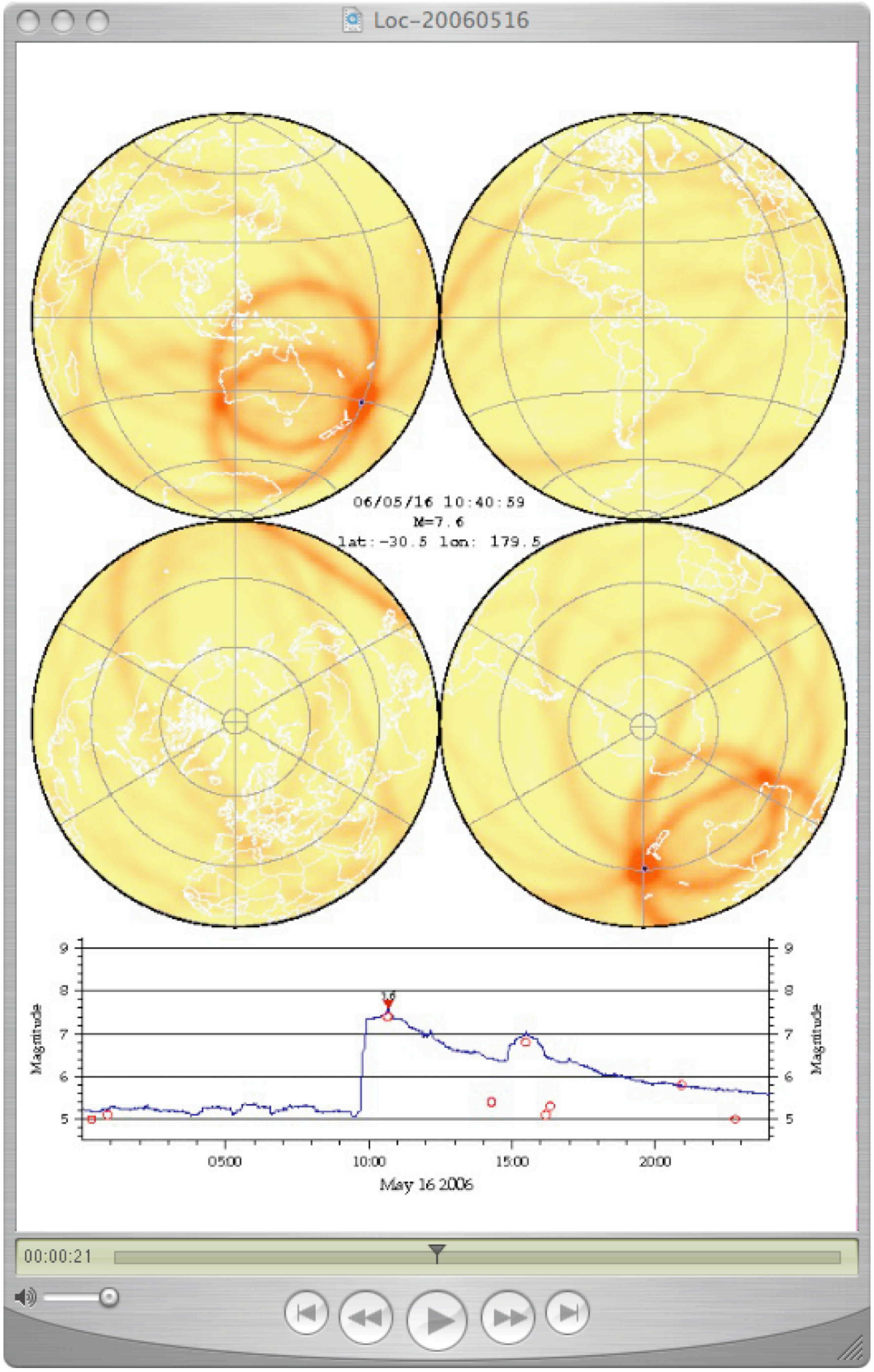

Figure 4: Screenshot of analysts' tool.

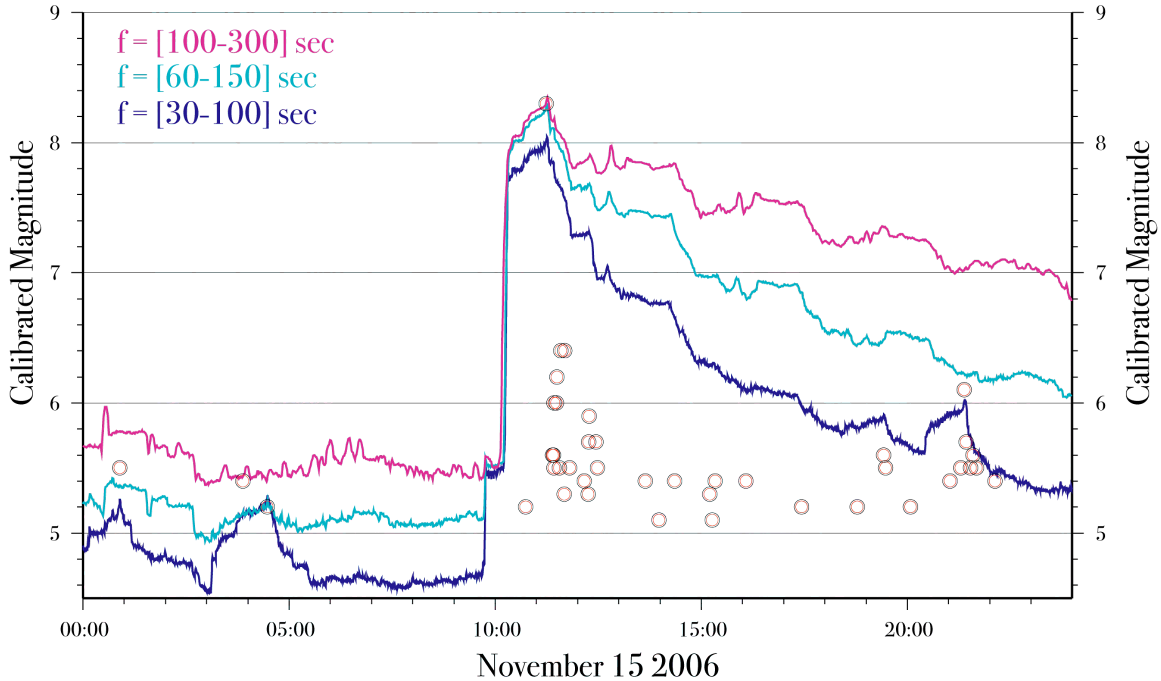

Figure 5: Example of results from three different frequency bands for one day of data. Catalog events greater than M5.0 are shown as circles.

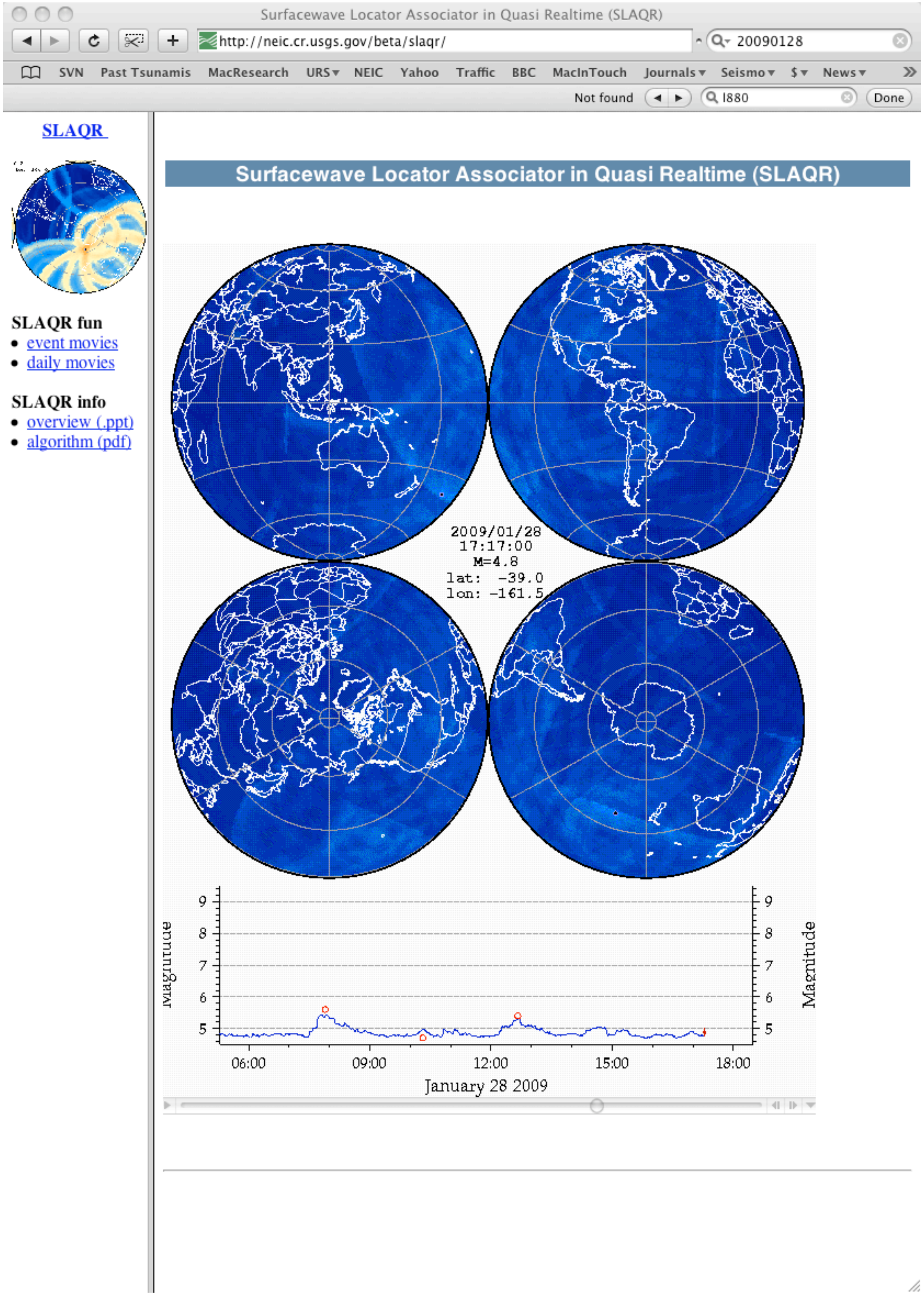

Figure 6. Web page (by P. Earle) of the pilot installation of the locator algorithm at the NEIC.